COST AND PERFORMANCE REPORT

EXECUTIVE SUMMARY

This report presents cost and performance data for a thermal desorption treatment application at the Outboard Marine Corporation (OMC) Superfund Site, located in Waukegan, Illinois. OMC performed marine product manufacturing operations at the site. Hydraulic fluid containing polychlorinated biphenyls (PCBs) was discharged through floor drains, resulting in the contamination of soil in several areas of the site and contamination of sediment in nearby Waukegan Harbor.

Based on a 1989 Consent Decree and Record of Decision, the remedial activities selected for the site included excavation, stockpiling, and treatment of PCB-contaminated soil and sediment. The specified cleanup goals for the site for PCBs was 97 percent removal by mass in treated soil and sediment. In addition, a destruction and removal efficiency (DRE) of 99.9999% for PCBs and a limit of 30 nanograms per dry standard cubic meter (ng/dscm) for dioxins and furans were required for stack gas emissions.

SoilTech's mobile Anaerobic Thermal Processor (ATP) system was selected for treating the PCB-contaminated soil and sediment at OMC. The SoilTech ATP system included a feed system, the ATP unit (rotary kiln thermal desorber), a vapor recovery system, a flue gas treatment system, and a tailings handling system. Wastewater from the vapor recovery system was treated in an on-site wastewater treatment system and then discharged to a sanitary sewer. Most of the PCBs desorbed from the contaminated soil and sediment were contained in oil from the vapor recovery system. Approximately 50,000 gallons of oil were generated during full-scale cleanup and were disposed off site. The treated soil and sediment were placed into containment cells constructed on site.

The ATP system was operated at the OMC site from January 22, 1992 until June 23, 1992 and was used to treat approximately 12,700 tons of PCB-contaminated soil and sediment. The ATP system met the cleanup goal for PCBs in soil and sediment by achieving an average removal efficiency of 99.98 percent for total PCBs. PCB concentrations in the treated soil ranged from 0.4 to 8.9 mg/kg. The PCB DRE of 99.9999% and total dioxin and furan stack emission requirements of 30 ng/dscm were met during the full-scale cleanup.

During the proof-of-process period (January 23 until March 5), the DRE for PCBs was not met, and EPA shut the system down. From March 5 until May 30, SoilTech made modifications to the ATP system, and the stack gas emissions requirements were met during the remainder of the soil cleanup.

A SITE Demonstration was conducted at the OMC site during June 1992. During this demonstration, 255 tons of soil and sediment were treated.

The remediation of contaminated soils and sediments at OMC was completed at a cost of $2,474,000 for activities directly attributed to treatment (corresponding to $190/ton of soil and sediment treated) and $900,000 for before-treatment activities.

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SITE INFORMATION

Identifying Information

Outboard Marine Corporation Superfund Site
Waukegan, Illinois
CERCLIS #: ILD000802827
ROD Date: 31 March 1989

Treatment Application

Type of Action: Remedial
Treatability Study Associated with Application? Yes (see Appendix A and Reference 6)
EPA SITE Program Test Associated with Application? Yes (see Reference 5)
Operation Period: 1/22/92 to 6/23/92
Quantity of Material Treated During Application: 12,755 tons of soil and sediment

Background

Historical Activity that Generated Contamination at the Site: Aluminum die-casting, machining

Corresponding SIC Code: 3363 (Aluminum Die-Castings)

Waste Management Practice that Contributed to Contamination: Discharge to Sewer/Surface Water, Surface Disposal Area

Site History: The Outboard Marine Corporation (OMC) Superfund Site is located in Waukegan, Illinois on the western shore of Lake Michigan, approximately 10 miles south of the Wisconsin border, as shown in Figure 1. OMC, a marine products manufacturer, used hydraulic fluid containing polychlorinated biphenyls (PCBs) as a lubricant for its aluminum casting and machining operations from 1961 to 1972. During these operations, hydraulic fluid was discharged through floor drains to an oil receptor system. The oil receptor system subsequently discharged to several areas at the site. It is estimated that approximately 700,000 pounds of PCBs were discharged to the OMC site and approximately 300,000 pounds of PCBs were discharged to Waukegan Harbor. The main areas of PCB contamination at the site, shown in Figure 2, are: Slip No. 3, a parking lot, the North Ditch, the Oval Lagoon, the Crescent Ditch, and Waukegan Harbor. [2, 3, 4, 5, and 12]

Regulatory Context: A Record of Decision (ROD) was signed in 1984 and engineering design work began in 1984. However, this work was suspended in late 1985 due to litigation between OMC and EPA concerning EPA's access to OMC property. In 1989, EPA and OMC negotiated a consent decree, and the 1984 ROD was amended in March 1989 to add a requirement for treatment of the contaminated soil and sediment on site. While the amended ROD did not require a specific treatment technology, the ROD did specify a treatment performance goal of 97 percent removal of PCBs.

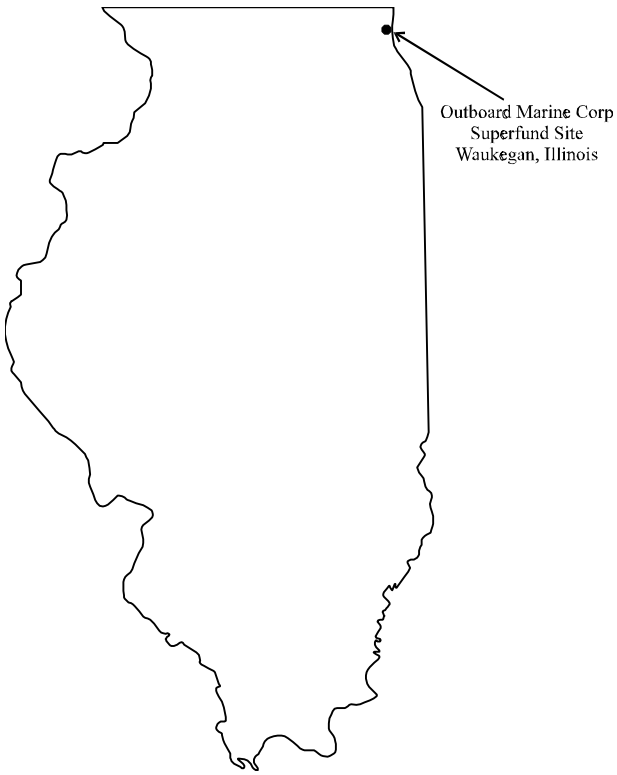

Figure 1. Site Location

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SITE INFORMATION (CONT.)

Background (cont.)

The following remedial actions were specified:

- Excavation and treatment of Slip No. 3 sediment with PCB concentrations greater than 500 ppm;
- Dredging of sediment in the Upper Harbor with PCB concentrations exceeding 50 ppm and placement of the dredged sediment in the Slip No. 3 containment cell for future treatment;
- Removal and treatment of soil and sediment in the Crescent Ditch and Oval Lagoon areas with PCB concentrations greater than 10,000 ppm;
- Construction of a containment cell at Slip No. 3;
- Construction of a new slip to replace Slip No. 3;
- Construction of a west containment cell to hold treated solids;
- Construction of an east containment cell in the parking lot area;
- Construction of a temporary on-site wastewater treatment facility for treatment of dredged water and a permanent wastewater treatment facility for treatment of containment cell wastewater;
- Capping of all containment cells; and
- Groundwater monitoring around the containment cells.

Figure 2 shows the areas at the site where PCB concentrations were between 50 and 500 ppm and areas where PCB concentrations exceeded 500 ppm.

Site Logistics/Contacts

Site Management: PRP Lead

Oversight: EPA

Remedial Project Manager:
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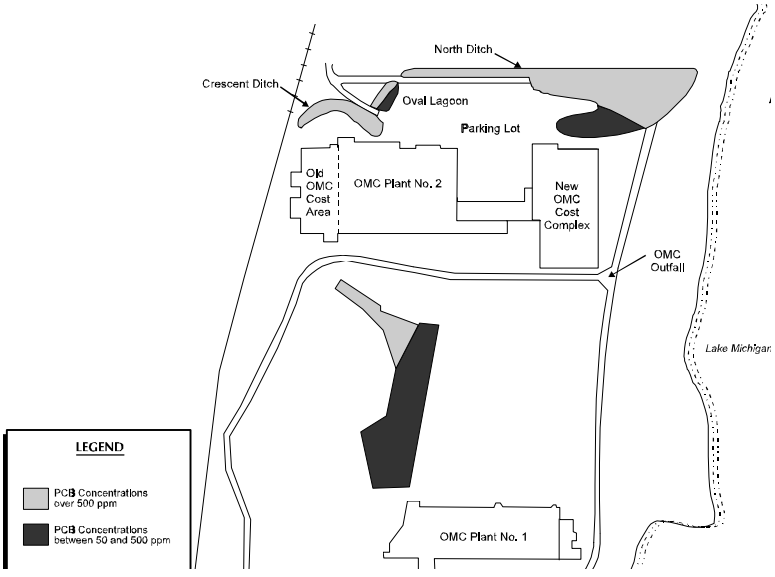

Figure 2. OMC Site Before Remedial Action (adapted from [4])

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MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Soil (ex situ), sediment (ex situ)

Contaminant Characterization

Primary Contaminant Groups: PCBs

The ROD specified excavation and treatment of soils from the Crescent Ditch and Oval Lagoon areas with PCB concentrations in excess of 10,000 ppm and sediments from Slip 3 with PCB concentrations grater than 500 ppm. The concentration of PCBs in the soil/sediment feed to the ATP unit (measured in daily composite samples collected from the feed conveyor to the ATP unit) ranged from 2,400 to 23,000 mg/kg. PCBs were measured in untreated soil/sediment samples using EPA Method 8080. [4, 5, 9, 10, and 13]

Matrix Characteristics Affecting Treatment Cost or Performance

The major matrix characteristics affecting cost or performance for this technology and their measured values are presented in Table 1.

Table 1. Matrix Characteristics [1,5]*

Parameter	Value	Measurement Method
Soil Classification	Sand	Not Reported
Bulk Density	1.87 g/cm ^{3}	Not Reported
Moisture Content	12.9%	Not Reported
pH	8.59	Not Reported
Total Organic Carbon	16,000 ppm	Not Reported
Total Petroleum Hydrocarbons	3,033 ppm	Not Reported
Chloride	303 ppm	Not Reported
Extractable Organic Halides	1,900 ppm	Not Reported
Particle Size Distribution		
<4.75 mm	5.55%	Not Reported
<4.75 mm > 2 mm	2.93%	Not Reported
< 2 mm > 0.425 mm	7.60%	Not Reported
<0.425 mm > 0.075 mm	68.69%	Not Reported
<0.075 mm > 0.005 mm	7.88%	Not Reported
<0.005 mm	5.67%	Not Reported
Lower Explosive Limit	Not Available	.

**The values presented in the table above are the average results for the three composite samples of the contaminated feed collected during the three test runs of the SITE Demonstration (conducted in June 1992).*

These values are representative of 255 of the 12,755 tons of soil and sediment treated at OMC and are the only data available at this time. The methods used to measure these parameters were not identified in available references.

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TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology Type

Thermal desorption

Supplemental Treatment Technology Types [5,11]

Post-treatment (air): The ATP system used at the OMC site included two off gas treatment systems. The flue gas treatment system designed to treat gases from the combustion zone of the ATP unit included the following technologies:

- Cyclone;
- Quench;
- Baghouse; and
- Carbon adsorption.

The vapor recovery system designed to treat vapors from the preheat and retort zones of the ATP unit consisted of the following technologies:

- Cyclone;
- Condenser; and
- Gas-oil-water separators.

Post-treatment (water): The condensed water from the vapor recovery system was discharged to an on-site wastewater treatment system utilizing sand filtration, Klensorb® filtration, ultraviolet oxidation, cartridge filtration (0.5 microns), and activated carbon filtration.

SoilTech ATP Thermal Desorption Technology Description and Operation

The SoilTech Anaerobic Thermal Processor (ATP), shown in Figure 3, is a mobile treatment system consisting of six main process units, including a soil pretreatment system, a feed system, an anaerobic thermal processor unit, a vapor recovery system, a flue gas treatment system, and a tailings handling system. [5]

The feed system consists of two feed hoppers and a conveyor belt. One feed hopper contains the contaminated soil and the other contains clean sand. The sand is fed to the ATP unit during system startup and shutdown periods, serving as a heat carrier. Sand was also fed during upset conditions. [5]

The ATP unit is a rotary kiln which contains four separate internal zones, separated using proprietary sand seals. As shown in Figure 4, these include the preheat, retort, combustion, and cooling zones. The feed enters the preheat zone where it is heated and mixed, vaporizing water, volatile organics, and some semivolatile organics. The solids then enter the retort zone where they are further heated, causing vaporization of heavy oils and some thermal cracking of hydrocarbons, resulting in the formation of coked solids and decontaminated solids. The solids from the retort zone then enter the combustion zone where coked solids are combusted. A portion of the decontaminated solids are recycled to the retort zone via a recycle channel. The recycling of these solids helps to maintain an elevated temperature in the retort zone. The decontaminated solids remaining in the combustion zone enter the cooling zone where they are cooled to an appropriate exit temperature. [5]

The vapor recovery system consists of two parallel systems. One system condenses water and vapors from the preheat zone of the ATP unit and consists of a cyclone, a condenser, and a gas-oil-water separator. The other system condenses water and vapors from the retort zone and consists of two cyclones, a scrubber, a fractionator, a condenser, and a gas-oil-water separator. Oil from the vapor recovery system containing PCBs is discharged to a storage tank for off-site disposal. During the full-scale treatment of 12,755 tons of soil and sediment at OMC, approximately 50,000 gallons of oil containing PCBs were collected and disposed off site. [5]

Condensed water from the vapor recovery system was treated in an on-site wastewater

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TREATMENT SYSTEM DESCRIPTION (CONT.)

SoilTech ATP Thermal Desorption Technology Description and Operation (cont.)

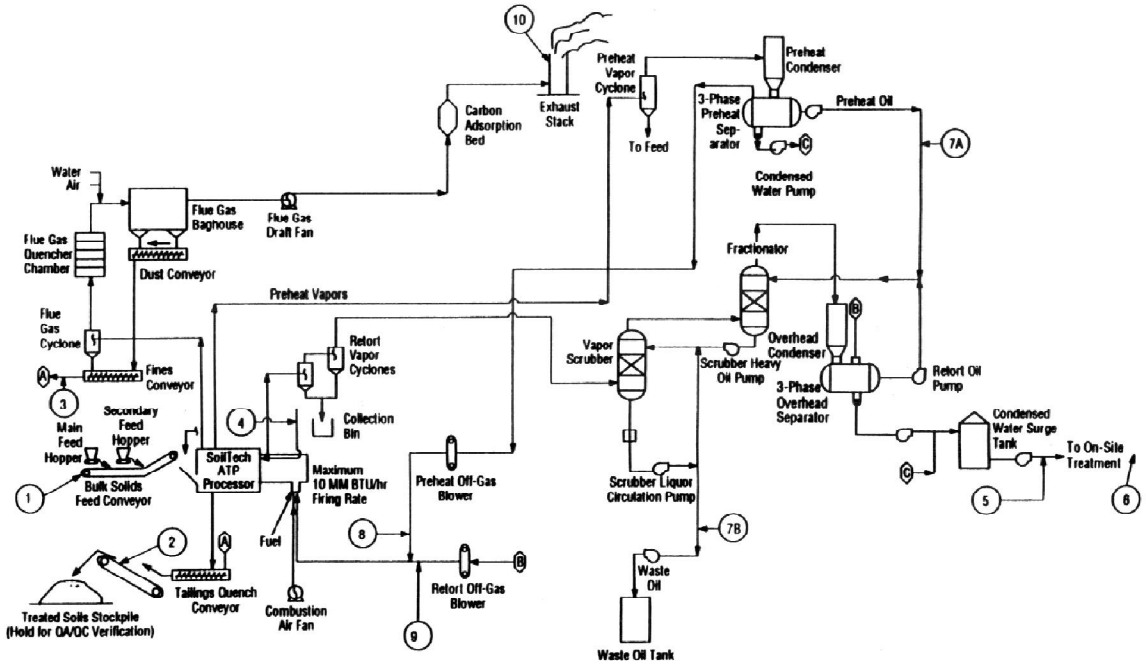

Figure 3. ATP Schematic [1]

treatment system, which consisted of the following treatment processes:

- Sand filtration;
- Klensorb® filtration;
- Ultraviolet oxidation;
- Cartridge filtration; and
- Carbon adsorption.

The wastewater from this system was discharged to a sanitary sewer. [11, 12]

Effluent testing following mobilization of the ATP unit to the site identified the presence of phenols, acetone, and other breakdown products. The wastewater system was modified to reduce phenol and acetone to levels acceptable for discharge to the sanitary sewer. [3]

The flue gas treatment system consists of a cyclone with fines conveyor, flue gas quencher chamber, baghouse with dust conveyor, acid gas scrubber, and activated carbon unit. This system removes particulates and trace hydrocarbons from the flue gas exiting the combustion zone of the ATP. Fines from the baghouse and cyclone are mixed with the treated solids exiting the ATP unit. The treated flue gas is released to the atmosphere. [5]

During the proof-of-process period (January 22, 1992 to March 5, 1992), the ATP system did not meet the stack gas emission requirement of 99.9999 percent DRE for PCBs. The ATP system was shut down on March 5, 1992 and the following modifications were made to the flue gas treatment system:

- The carbon bed depth in the stack was increased to 24 inches;
- The scrubber was converted to an adsorption unit by adding two new carbon beds to the scrubber; and
- Activated carbon beds were installed in the vapor return lines for the preheat and retort zones.

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TREATMENT SYSTEM DESCRIPTION (CONT.)

SoilTech ATP Thermal Desorption Technology Description and Operation (cont.)

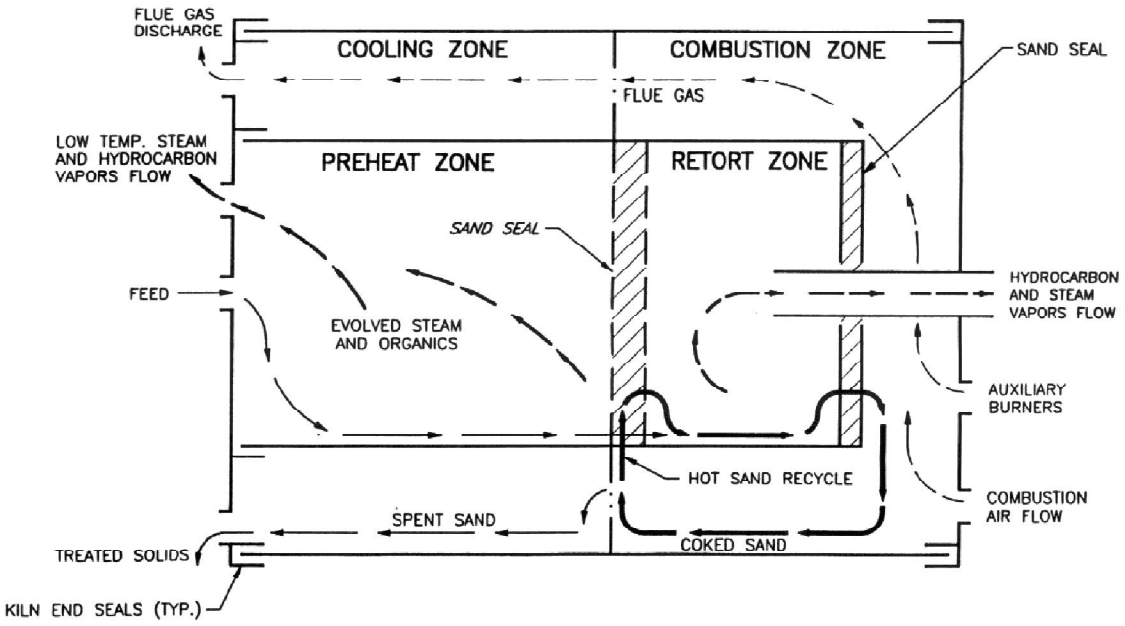

Figure 4. Simplified Sectional Diagram Showing the Four Internal Zones [5]

In early May, SoilTech discovered a gap in the flue gas carbon bed seal, which allowed an estimated 70% of the flue gas stream to bypass the carbon bed. This problem was corrected prior to the stack gas testing on May 12. The PCB DRE of 99.9999% was achieved during the remainder of this application. [12]

The tailings (treated solids) handling system was used to cool and remove treated solids from the ATP. The treated solids exiting the ATP were quenched with process and scrubber water and transported to storage piles using belt and screw conveyors. [5]

The primary innovative features of the ATP unit are the four internal zones and the use of proprietary sand seals at each end of the retort zone which are designed to maintain an oxygen-free environment in the retort zone. The oxygen-free environment in the retort zone helps to prevent the oxidation of hydrocarbons and coke. [5]

A SITE Demonstration was conducted at the OMC site in June 1992. The purpose of the SITE demonstration was to obtain information on the performance and cost of the technology and to assess its effectiveness at the OMC site. During the three test runs of the demonstration, 255 tons of soil and sediment were treated. [1]

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TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance [5,12]

The major operating parameters affecting cost or performance for this technology and the values measured for each during this treatment application are presented in Table 2.

The average preheat and retort zone off-gas flow rates measured during the SITE Demonstration were 211 and 88 actual cubic feed per minute (acfm), respectively. The average stack gas flow rate during the SITE Demonstration was 6,580 standard cubic feet per minute (scfm).

Table 2. Operating Parameters [5, 12]*

Parameter	Value	Measurement Method
Operating Pressure	Negative pressure	Pressure to electrical transducer
Preheat and Retort Zone Residence Time	30 to 40 minutes	Engineering design calculations
Preheat Zone Temperature	851°F	Thermocouples in preheat zone
Retort Zone Temperature	1,207°F	Thermocouples in retort zone
Combustion Zone Temperature	1,339°F	Thermocouples in combustion zone
Cooling Zone Temperature	764°F	Thermocouples on cooling zone
System Throughput	8.31 tons per hour	Weight of treated solids measured using a truck scale

**The values presented in the table above are the average results for the three test runs of the SITE Demonstration conducted in June 1992. They are based on the operating conditions used for treating 255 of the 12,755 tons of soil and sediment at OMC. [5, 12]*

Timeline

The timeline for this application is presented in Table 3.

Table 3. Timeline [1, 2, 4, 5, 9, 10, 11, and 12]

Start Date	End Date	Activity
1961	1972	OMC used hydraulic fluid that contained PCBs in its manufacturing operations.
May 15, 1984	.	ROD signed.
March 31, 1989	.	Consent Decree signed and ROD amended requiring on-site treatment rather than off-site disposal of contaminated soil and sediment.
1989	.	Site construction activities initiated, including stockpiling of soil and sediment for treatment.
November 1991	January 1992	SoilTech ATP system assembled and shakedown of system conducted.
January 22, 1992	February 24, 1992	Contaminated soil and sediment treated using the ATP system (30-day proof-of-process period).
February 24, 1992	February 29, 1992	ATP system shutdown for maintenance.
March 1, 1992	March 5, 1992	System restarted but shut down 5 days later by EPA due to nonattainment of stack gas emission standards.
March 5, 1992	March 17, 1992	ATP system modified.
March 17, 1992	March 18, 1992	Stack gas testing conducted.
March 19, 1992	April 9, 1992	ATP system modified.
April 8, 1992	April 16, 1992	Stack gas testing conducted.
April 17, 1992	May 12, 1992	ATP system modified.
May 12, 1992	May 14, 1992	Stack gas testing conducted. Emissions standards met.
May 30, 1992	June 15, 1992	ATP system restarted and operated continuously.
June 16, 1992	June 19, 1992	SITE Demonstration conducted.
June 20, 1992	June 23, 1992	Treatment of soil and sediment using the ATP system completed.

RPF-048.pm5\10018-01.pm5

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Requirements [4, 5, and 12]

The 1989 ROD specified a cleanup goal for PCBs in soil and sediment of 97 percent removal by mass. Stack gas emission requirements were specified in the Consent Decree for PCBs (99.9999 percent destruction and removal efficiency (DRE) for PCBs). A stack gas emission requirement for dioxins and furans of 30 nanograms per dry standard cubic meter (ng/dscm) was also specified by EPA.

Additional Information on Goals [5, 9, 10, 11, and 12]

The 1989 ROD stated that sediment from Slip No. 3 and Waukegan Harbor with PCB concentrations exceeding 500 ppm and soil and sediment from the Crescent Ditch and Oval Lagoon areas with PCB concentrations exceeding 10,000 ppm required on-site treatment.

Treatment Performance Data [9, 10, 11, and 12]

Table 4 summarizes the analytical results for PCBs in untreated soil/sediment and treated soil/sediment during the treatment application at OMC. Appendix B contains PCB analytical results for each day samples were collected.

Table 5 shows stack gas results for the PCB DRE and total dioxin and furan concentration during the proof-of-process and modifications period (samples collected from 1-28-92 to 4-10-92). Table 6 shows stack gas results for the PCB DRE and total dioxin and furan concentration after the process modifications were completed (samples collected from 5/12/92 to 6/16/92). Appendix B contains the results for each stack gas test conducted at OMC.

Table 4. PCB Analytical Results [9, 10, 11]

	Range	Average	Number of Data Points
Untreated Soil/Sediment	2,400 to 23,000 mg/kg	10,484 mg/kg	75
Treated Soil/Sediment	0.4 to 8.9 mg/kg	2.2 mg/kg	75
PCB Removal Efficiency	99.91 to >99.99%	99.98%	N/A

N/A - Not applicable.

Table 5. Stack Gas Results During Proof -of -Process Period (Samples taken between 1/28/92 and 4/10/92) [10,11]

	Range	Number of Data Points
PCB DRE	99.568 to 99.99968%	10
Total Dioxin/Furan Concentration	19.66 to 1,037 ng/dscm at 7% O_2	10

Table 6. Stack Gas Results After Process Modifications Completed (Samples taken between 5/12/92 and 6/16/92) [10,11]

	Range	Number of Data Points
PCB DRE	99.99991 to 99.99999%	8
Total Dioxin/Furan Concentration	NA	0

NA - Not analyzed.

RPF-048.pm5\10018-01.pm5

TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data [9,10,11,12] (cont.)

During the SITE Demonstration conducted at the OMC site in June 1992, stack gas emissions were analyzed for individual dioxins and furans during three test runs. The results, shown in Table 7, indicate that only TCDF was present at detectable levels. [5]

The PCB results for untreated soil/sediment and treated soil/sediment presented in Table 4 are for composite samples collected each day the system was operated. Soil/sediment and stack gas samples were analyzed for PCBs using EPA Method 8080. Stack gas samples were analyzed for dioxins and furans using EPA Method 8280. [5, 9, 10, 11, 12, and 13]

Table 7. Dioxin and Furan Stack Gas Emissions Measured During the SITE Demonstration [5]

Compound	Average Dioxin and Furan Concentrations in Stack Gas Emissions (ng/dscm)
Tetrachlorinated dibenzo-p-dioxins (TCDD)	<0.029
Tetrachlorinated dibenzofurans (TCDF)	0.0787
Pentachlorinated dibenzofurans (PeCDF)	<0.022
Hexachlorinated dibenzofurans (HxCDF)	<0.018
TOTAL	0.0787 [a]

[a] *Total stack gas concentration of 0.0787 ng/dscm is equivalent to a 2,3,7,8-TCDD concentration of zero.*

Performance Data Assessment

As shown in Table 4 and Appendix B, the SoilTech ATP system achieved the cleanup goal of 97% removal by mass of PCBs in soil and sediment, achieving an average PCB removal efficiency of 99.98%. Treated soil PCB concentrations ranged from 0.4 to 8.9 mg/kg. The PCB DRE requirement was achieved for stack gas emissions after the process modifications described above were made in early May 1992.

As shown in Table 5 and Appendix B, the concentration of total dioxins and furans in the stack gas was less than the stack gas emission requirement of 30 nanograms per dry standard cubic meter (ng/dscm) in 3 of the 10 stack gas tests conducted prior to completing the process modifications described above. The concentrations of total dioxins and furans measured near the conclusion of the modifications period (4/10/92) was 24.7 ng/dscm. Total dioxins and furans were not analyzed in subsequent stack gas tests. The concentration of total dioxins and furans in the stack gas during the three test runs conducted during the SITE Demonstration on June 16, 1992 was 0.0787 ng/dscm.

Performance Data Completeness

Paired untreated and treated soil and sediment concentrations were obtained for each day of operation of the ATP system at the OMC site. Daily values for operating parameters, however, are not available.

Performance Data Quality

EPA SW-846 methods were used for analysis of the soil samples and stack gas emissions in this application. No exceptions to the QA/QC requirements were noted in the available reference.

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TREATMENT SYSTEM COST

Procurement Process

The potentially responsible parties (PRPs) for this site selected Canonie Environmental Services to provide the engineering design and construction services for the OMC/Waukegan Harbor project through a competitive procurement procedure. Canoine subcontracted SoilTech ATP Systems, Inc. to treat the PCB-contaminated soil/sediment using the SoilTech ATP system.

Treatment System Cost

SoilTech was contracted to remediate the soils and sediments at OMC for $700,000 in fixed costs and $185 per ton of material processed. These costs did not include utilities, site preparation, excavation of contaminated soil, or disposal of PCB condensate produced. [14]

Tables 8 and 9 present the actual costs for the thermal desorption application at OMC. In order to standardize reporting of costs across projects, costs are shown in Tables 8 and 9 according to the format for an interagency Work Breakdown Structure (WBS). The WBS specifies 9 before-treatment cost elements, 5 after-treatment cost elements, and 12 cost elements that provide a detailed breakdown of costs directly associated with treatment. Tables 8 and 9 present the cost elements exactly as they appear in the WBS, along with the specific activities, as provided by EPA in the Draft Applications Analysis Report.

In preparing the Applications Analysis Report, EPA obtained actual cost data from SoilTech for treating 12,755 tons of soil at OMC. [5]

The cost data in Table 8 show a total of $2,474,000 for cost elements directly associated with treatment of 12,755 tons of soil (i.e., excluding before and after treatment cost elements). This total treatment cost corresponds to $190 per ton of soil treated. In addition, Table 9 shows a total of $900,000 for before-treatment costs. There were no costs in this application for the following elements in the WBS: Liquid Preparation and Handling, Vapor/Gas Preparation and Handling, Pads/Foundations/Spill Control, Training, Operation (Long Term - Over 3 Years), Dismantling, Site Work, Surface Water Collection and Control, Air Pollution/Gas Collection and Control, Solids Collection and Containment, Liquids/Sediments/Sludges Collection and Containment, Drums/Tanks/Structures/ Miscellaneous Demolition and Removal, Decontamination and Decommissioning, Disposal (Other than Commercial), Disposal (Commercial), Site Restoration, and Demobilization.

Table 8. Costs Directly Associated with Treatment [5]

Cost Elements	Cost (dollars)
Solids Preparation and Handling - residuals and waste handling and transporting	186,000
Startup/Testing/Permits - permitting and regulatory - startup	 188,000 158,000
Operation (Short Term - Up to 3 years) - labor - supplies and consumables - utilities - equipment repair and replacement	 854,000 139,000 65,000 133,000
Cost of Ownership - capital equipment	361,000
Demobilization	390,000
TOTAL DIRECT TREATMENT COSTS	2,474,000

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TREATMENT SYSTEM COST (CONT.)

Treatment System Cost (cont.)

Table 9. Before-Treatment Cost Elements [5]

Cost Elements	Costs (dollars)
Mobilization and Preparatory Work - transport of ATP unit to site - initial setup - installing fence around location for ATP unit	655,000
Monitoring, Sampling, Testing and Analysis - effluent monitoring - analytical services	207,000 38,000
TOTAL BEFORE TREATMENT COSTS	900,000

Cost Data Quality

Treatment cost information shown in Table 8 represents actual costs for this application, and include costs for seven specific elements in the WBS.

Vendor Input

According to the treatment vendor, in general, the costs for treatment using the SoilTech ATP system vary depending on the character of the waste material, with treatment costs ranging from $150 to $250 per ton for a 10-ton per hour ATP System. The factors identified by the vendor that affect costs include:

- Moisture content of feed material;
- Particle size;
- Hydrocarbon content;
- Material handling characteristics; and
- Chemical characteristics.

Vendor estimates for mobilization and demobilization costs for a 10-ton per hour system range from $700,000 to $1.5 million. [12]

OBSERVATIONS AND LESSONS LEARNED

Cost Observations and Lessons Learned

- The actual cost for activities directly related to treatment was $2,474,000 which corresponds to $190 per ton of soil treated.
- A total of $900,000 was expended in this application for before-treatment activities, including mobilization and preparatory work and monitoring, sampling, testing, and analysis.

Performance Observations and Lessons Learned

- The ATP system achieved an average mass removal efficiency of 99.98 percent for PCBs during the full-scale cleanup; this was much higher than the PCB soil/sediment cleanup goal of 97 percent removal. Treated soil PCB concentrations ranged from 0.4 to 8.9 mg/kg.
- The PCB DRE and total dioxin and furan stack gas emission requirements of 99.9999% DRE and 30 ng/dscm, respectively, were met after making several modifications to the flue gas treatment system.
- The majority of PCBs accumulated in the vapor scrubber oils. Approximately 50,000 gallons of oil were generated during full-scale cleanup and were disposed off site.

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OBSERVATIONS AND LESSONS LEARNED (CONT.)

Other Observations and Lessons Learned

- Bench-scale treatability study results were an accurate predictor of full-scale PCB removal and indicated that a thermal treatment system removed more than 99% of a PCB congener from the soil/sediment at OMC.
- Pilot study testing of effluent was limited to PCBs and total suspended solids (TSS). Discharged water was subject to a limit of 1 part-per-billion (ppb) for PCBs. Effluent testing following mobilization of the ATP unit to the site identified the presence of contaminants including phenols and acetone. The wastewater system was modified to reduce phenol and acetone levels to acceptable levels for discharge to a POTW. PCB levels were less than the 1 ppb limit.

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Analysis Preparation

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RPF-048.pm5\10018-01.pm5

APPENDIX A—TREATABILITY STUDY RESULTS

Treatability Study Objectives [6]

- Determine the effectiveness of a thermal treatment system for treating different matrices containing polychlorinated biphenyls (PCBs) at the Outboard Marine Corporation (OMC) Superfund Site.
- Assess the affect of varying process operating conditions, including residence time and type of feed material, on the treatment effectiveness and concentration of PCBs in the treatment residuals.
- Determine if PCBs break down during the treatment process.
- Determine if the char and ash residuals contain dioxins.
- Obtain data needed to evaluate the operation of a thermal treatment system to be used for a full-scale remediation of the OMC site.

Treatability Study Test Description

System Description: The bench-scale system, shown in Figure A-1, consisted of a 12-inch by 12-inch rotary kiln, a hot vapor condenser, a condensed liquid collector, a gas filter, a gas compressor, and a gas sample bomb. Material was fed into the kiln through a 4-inch port, and treated solids were withdrawn through the same port. Vapors from the kiln were condensed and collected. Condensed vapors were separated into water, oil, and sludge subfractions. Non-condensible gasses were filtered, measured, and collected. Treatment residuals included treated solids (char and ash), water, oil, and gasses.

Feed Material: The PCB-contaminated material (feed material) used in the treatability study included organic silt (muck) and sand that were collected from a soil boring at the site (the Crescent Ditch area near a former outfall). The muck was an oily sediment, containing leaves and other decomposing material, with a high water content. The sand was fine, of uniform size, with a high water content. The sand was used as the feed material for Run No. 2; the muck was used at the feed material for Run No. 1; and muck mixed with clean sand was used as the feed

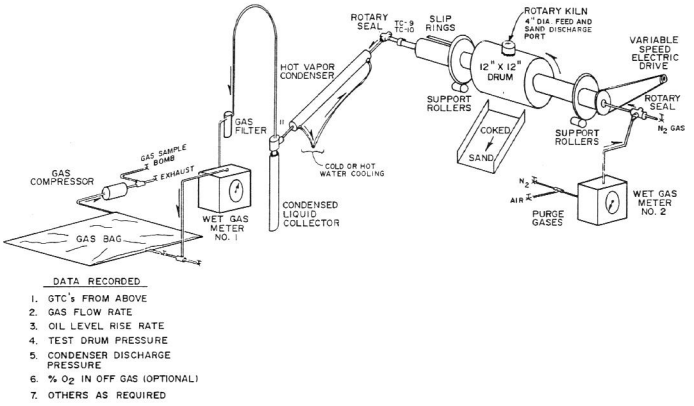

Figure A-1 - Bench-Scale Treatability Test System [6]

Note: Not to scale.

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APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

Treatability Study Test Description (cont.)

material for Run Nos. 3 and 4, as described below.

Test Runs: The study consisted of four test runs. For each run (batch) treated, two residual fractions of volatilized liquids were collected; one fraction (referred to as the retort water) was collected at a kiln temperature of approximately 375-500°F; the second fraction (referred to as the retort oil) was collected at a kiln temperature of approximately 650-1,116°F. These fractions were subdivided for chemical analysis into oil, water, and sludge subfractions. The test runs were conducted under the following conditions, as summarized in Table A-1.

- Run No. 1: The feed consisted of Crescent Ditch muck. The rotary kiln was preheated to 300°F and the temperature in the kiln was increased stepwise to a maximum kiln temperature of 1,116°F. The total residence time for the run was 117 minutes.
- Run No. 2: The feed consisted of Crescent Ditch sand. For this run, the rotary kiln was not preheated. Upon addition of the sand, the temperature was increased stepwise to a maximum kiln temperature of 1,085°F. The total residence time for the run was 118 minutes.
- Run No. 3: The test conditions for Run No. 3 were the same as used in Run No. 1 except the feed consisted of a mixture of clean sand and Crescent Ditch muck at a ratio of 2.2:1 of sand:muck. In this run, the rotary kiln was not preheated, the maximum kiln temperature was 1,088°F, and the residence time was increased to 171 minutes.
- Run No. 4: The test conditions for Run No. 4 were the same as for Run No. 3 except the maximum kiln temperature was 1,059°F, and the residence time was 90 minutes.

Table A-1. Test Conditions [6]

Parameter	Run No. 1	Run No. 2	Run No. 3	Run No. 4
Feed Material	Muck	Sand	Muck and Clean Sand	Muck and Clean Sand
Mass of Feed Material (grams)	1,212.9	3,711.7	3,490.1	827.8
Rotational Speed of Kiln (rpm)	3.5	3.5	3.5	3.5
Maximum Temperature of Heating Chamber (°F)	1,116	1,085	1,088	1,059
Residence Time (min)	117	118	171	90

Treatability Study Performance Data and Analysis

Treatment Performance Data: Feed materials and solid and liquid residuals were collected and analyzed for PCB 1242 (gaseous residuals were not analyzed). Table A-2 shows the concentration of PCB 1242 in the untreated feed materials and treated solids, and the calculated percent removal, for the four test runs. PCB 1242 was analyzed for in the feed material for Run Nos. 1 and 2 only (feed materials were analyzed twice for PCB 1242 in these runs), and the treated solids from Run Nos. 1, 2, and 3 only; the reason for not analyzing untreated feed from Run Nos. 3 and 4, or treated solids from Run No. 4, is not available at this time.

Table A-3 shows the concentrations of PCB 1242 in the liquid residuals (oil, water, and sludge), and the volume of liquid residuals, for the first two test runs. Data for liquid residuals from the latter two test runs are not available at this time.

RPF-048.pm5\10018-01.pm5

APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

Treatability Study Performance Data and Analysis (cont.)

Table A-2. Treatment Performance Data [6]

Run No.	Untreated Feed Analysis 1	Untreated Feed Analysis 2	Treated Solids	Percent Removal (%)
1	61,335	16,866	ND (0.1)	>99
2	26,437	28,900	ND (0.1)	>99
3	NA	—	ND (0.1)	NA
4	NA	—	NA	NA

ND = Not detected. Number in parentheses is the reported detection limit.
NA = Not available.

Table A-3. Liquid Residuals Analytical Data and Volume Measured [6]

Fraction	Run No.1 PCB 1242 Concentration (mg/L)	Run No.1 Fraction Volume (mL)	Run No. 2 PCB 1242 Concentration (mg/L)	Run No. 2 Fraction Volumes (mL)
Retort Water				
Oil	50,877	4	68,861	24
Water	70	602.9	114	502.4
Sludge	5,492	8.1	10,223	trace
Retort Oil				
Oil	235,308	86.3	959,170	49.3
Water	16	44.3	12	32.1

The char and ash from Run No. 1 were analyzed for 2,3,7,8-tetrachlorodibenzo-p-dioxin. The concentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin in the char and ash products from Run No. 1 was less than the reported detection limit of 0.3 ng/g.

Performance Data Assessment: The performance data comparing PCB concentrations in untreated feed and treated solids (Table 2) shows that the thermal treatment system removed more than 99% of PCB 1242 and achieved a concentration in the treated solids of less than the analytical detection limit (0.1 mg/kg) for both muck and sand feed materials.

Varying feed material (muck and sand) did not appear to affect the treatment performance achieved by the thermal desorption system, but did affect the concentration of PCB 1242 in the liquid residuals. Treatment of sand generated higher concentrations of PCB 1242 in the retort water and oil than treatment of muck. Insufficient data were collected to determine whether residence time affected treatment effectiveness or concentration of PCBs in the treatment residuals. Insufficient data were collected to assess the effectiveness of treating mixtures of muck and clean sand.

To determine if PCBs break down during the treatment process, the mass of PCB 1242 fed to the treatment system was compared with the mass of PCB 1242 exiting the system. This calculation, shown below in Table A-4, provides inconclusive information concerning the potential breakdown of PCBs.

Table A-4 shows that the mass of PCB 1242 entering and exiting the system compared well for Run No. 1 (20.5 gm entering and 20.6 gm exiting), and not as well for Run No. 2 (107.3 gm entering and 49.1 gm exiting). Although different materials were fed to the system in the two runs (muck and sand), which may account for the variation in results, it seems more likely that the variation in results is due to uncertainties concerning analytical accuracy, potential losses of PCBs in gas streams or as coatings on collection lines or because of lack of homogeneity in samples of feed material. Dilutions of up to 30,000 to 1 were used to quantitate the PCB concentrations in feed materials and treatment residu-

RPF-048.pm5\10018-01.pm5

APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

Treatability Study Performance Data and Analysis (cont.)

*Table A-4. Calculated Mass of PCB 1242 in Run Nos. 1 and 2**

	Quantity of Material	PCB 1242 Concentration	Mass of PCB 1242 (gm)
Run No. 1			
Feed Material	1,212.9 gm	16,866 mg/kg	20.5
Retort Water			
Oil	4 mL	50,877 mg/L	0.2
Water	602.9 mL	70 mg/L	0.04
Sludge	8.1 mL	5,492 mg/L	0.04
Retort Oil			
Oil	86.3 mL	235,308 mg/L	20.3
Water	44.3 mL	16 mg/L	0.0007
Run No. 2			
Feed Material	3,711.7 gm	28,900 mg/kg	107.3
Retort Water			
Oil	24 mL	68,861 mg/L	1.7
Water	502.4 mL	114 mg/L	0.06
Sludge	trace	10,223 mg/L	—
Retort Oil			
Oil	49.3 mL	959,170 mg/L	47.3
Water	32.1 mL	12 mg/L	0.0004

**Treated solids are not shown on this table because PCB 1242 was not detected in this residual.*

als. Dilutions of this magnitude tend to limit the accuracy of analytical results; the treatment vendor indicated that additional laboratory work was required to improve the accuracy of the results.

Limited data were collected to determine if dioxins appear in the treatment residuals. The one sample of char and ash analyzed for dioxins showed that the concentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin was less than the reported detection limit of 0.3 ng/gm.

Limited data needed to evaluate the operation of a thermal treatment system to be used for a full-scale remediation of the OMC site were obtained during this treatability study. Treatment performance data were obtained on the affect of varying feed materials, but not on the affect of varying kiln temperature or residence time. Additional data on concentrations of PCBs in liquid residuals collected at varying temperatures were also obtained during this study.

Performance Data Completeness: Data are available to perform a limited material balance on PCB 1242 concentrations during two test runs of this study, including data on untreated feed materials, treated solids, and liquid residuals. No data are available on off-gasses from the system. Information linking treatment performance with key operating parameters (temperature, residence time) are also available for this study.

Performance Data Quality: Several items concerning limitations on analytical data quality were identified during this study, including dilution and lack of homogeneity of samples. Samples were required to be diluted up to 30,000 to one prior to chemical analysis for PCB 1242. Such dilutions (over 4 orders of magnitude) tend to limit the accuracy of analytical results. Multi-phase samples (e.g., feed materials) were mixed prior to chemical analysis. Mixing may not have produced a completely homogeneous sample for analysis.

RPF-048.pm5\1018-01.pm5

APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

Observations and Lessons Learned

Performance Observations and Lessons Learned

- Treatment performance data indicated that the thermal treatment system removed more than 99% of PCB 1242, and achieved a concentration in the treated solids of less than the analytical detection limit (0.1 mg/kg) for both muck and sand feed materials.
- Preliminary results were inconclusive in showing whether PCBs break down during treatment.
- The char and ash residuals did not contain detectable levels of 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Other Observations and Lessons Learned

- The water and oil residuals produced during treatment contained PCBs, and the oil contained the highest concentrations of PCBs.
- Analytical limitations regarding sampling dilution and lack of homogeneity limited the usefulness of this study.
- Because mixed clean sand/contaminated media feed materials were not tested in this study, information useful for scale-up under these conditions was not obtained during this study.

APPENDIX B—ANALYTICAL RESULTS

PCB Analytical Results Untreated and Treated Soil/Sediment [10, 11]

Sample Date	Untreated Soil/Sediment Concentration(a) (mg/kg)	Treated Soil/Sediment Concentration(a) (mg/kg)	PCB Removal Efficiency (%)
01/22/9	11,000	2.2	99.98
01/23/9	23,000	2.2	99.99
01/24/9	15,000	4.5	99.97
01/25/9	13,000	5.9	99.95
01/26/9	8,500	7.4	99.91
01/27/9	9,600	8.9	99.91
01/28/9	9,600	1.2	99.99
01/29/9	2,400	1.5	99.94
01/30/9	9,600	3.9	99.96
01/31/9	12,000	5.9	99.95
02/01/9	13,000	3.7	99.97
02/02/9	8,600	1.6	99.98
02/03/9	14,000	3.5	99.98
02/04/9	15,000	2.1	99.99
02/05/9	10,000	2.5	99.98
02/06/9	12,000	1.5	99.99
02/07/9	12,000	1.5	99.99
02/08/9	10,000	2	99.98
02/09/9	12,000	1.8	99.99
02/10/9	14,000	1.2	99.99
02/11/9	14,000	2.3	99.98

Sample Date	Untreated Soil/Sediment Concentration(a) (mg/kg)	Treated Soil/Sediment Concentration(a) (mg/kg)	PCB Removal Efficiency (%)
02/12/9	12,000	3.9	99.97
02/13/9	13,000	2.4	99.98
02/14/9	14,000	2.9	99.98
02/15/9	13,000	3.8	99.97
02/16/9	11,000	2.1	99.98
02/17/9	9,200	4.1	99.96
02/18/9	9,000	1.4	99.98
02/19/9	9,500	1.5	99.98
02/20/9	10,000	2.5	99.98
02/21/9	11,000	2.2	99.98
02/22/9	7,300	1.3	99.98
02/23/9	6,900	1.8	99.97
02/24/9	7,300	1.6	99.98
02/29/9	7,500	0.99	99.99
03/01/9	7,900	0.86	99.99
03/02/9	6,400	0.43	99.99
03/03/9	8,100	0.51	99.99
03/04/9	6,600	0.61	99.99
03/05/9	6,300	0.53	99.99
03/17/9	9,900	1.4	99.99
03/18/9	10,000	3.8	99.96

RPF-048.pm5\10018-01.pm5

APPENDIX B—ANALYTICAL RESULTS (CONT.)

PCB Analytical Results Untreated and Treated Soil/Sediment (continued)

Sample Date	Untreated Soil/Sediment Concentration(a) (mg/kg)	Treated Soil/Sediment Concentration(a) (mg/kg)	PCB Removal Efficiency (%)
04/08/9	9,200	1.5	99.98
04/09/9	8,600	1	99.99
04/10/9	9,000	1.1	99.99
04/12/9	8,700	1.4	99.98
04/13/9	11,000	0.93	99.99
04/14/9	14,000	2.3	99.98
04/15/9	14,000	1.3	99.99
04/16/9	21,000	1.2	99.99
05/12/9	5,400	0.95	99.98
05/13/9	10,000	2	99.98
05/14/9	11,000	1.2	99.99
05/30/9	12,000	0.69	99.99
05/31/9	9,200	0.57	99.99
06/01/9	12,000	0.72	99.99
06/02/9	12,000	1.3	99.99
06/03/9	10,000	0.82	99.99
06/04/9	9,200	0.4	99.99
06/05/9	11,000	0.43	99.99
06/06/9	10,000	7.1	99.93
06/07/9	9,400	3.1	99.97
06/08/9	8,000	1.3	99.98
06/09/9	8,900	1.1	99.99
06/10/9	11,000	1.8	99.98
06/11/9	9,700	0.61	99.99
06/12/9	9,700	1.4	99.99
06/15/9	10,000	1.6	99.98
06/16/9	10,000	0.71	99.99
06/17/9	8,600	1	99.99
06/18/9	10,000	1.7	99.98
06/19/9	11,000	0.75	99.99
06/20/9	9,900	2.6	99.97
06/21/9	9,800	4.8	99.95
06/22/9	8,800	5	99.94

(a)Untreated and treated soil/sediment concentrations are based on composites generated from 8:00 AM on the corresponding date to 8:00 AM the next morning.

Stack Gas Test Results [11]

Stack Gas Test Date	PCB DRE (%)	Total Dioxin/Furan Concentration (ng/dscm at 7% O_2)
01/28/92	99.9925	1,037.00
02/04/92	99.9568	19.66
02/10/92	99.9708	661.60
02/18/92	99.9944	289.80
03/04/92	99.9962	109.40
03/05/92	99.9985	71.43
03/05/92	99.9992	31.84
03/17/92	99.99944	13.74
04/09/92	99.99768	77.8
04/10/92	99.99968	24.7
05/12/92	99.99991	NA
05/13/92	99.99997	NA
05/13/92	99.99997	NA
05/14/92	99.99998	NA
06/02/92	99.99994	NA
06/02/92	99.99991	NA
06/09/92	99.99997	NA
06/16/92	99.99999	NA

NA = Not Analyzed.

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COST AND PERFORMANCE REPORT

Thermal Desorption
at the
Outboard Marine Corporation Superfund Site,
Waukegan, Illinois

Prepared By:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

March 1995

Notice

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